USAFETAC TN 71-8

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)

USAF ENVIRONMENTAL
TECHNICAL APPLICATIONS CENTER

BUILDING 159
NAVY YARD ANNEX
WASHINGTON, D.C. 20333

TECHNICAL NOTE
71-8

A PREDICTION METHOD FOR BLAST FOCUSING

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SEPTEMBER 1971

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32

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) USAF Environmental Technical Applications Center, Bldg 159, Navy Yard Annex, Washington, D.C. 20333	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. REPORT TITLE A Prediction Method for Blast Focusing	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Note 71-8	
5. AUTHOR(S) (First name, middle initial, last name) Captain Richard A. Rasmussen	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1971	34	3

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Hq Air Weather Service (MAC) Scott AFB, IL 62225

13. ABSTRACT

This report discusses an over-pressure forecasting technique established by the Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground, Md. The method involves calculating the forecast representative value of the speed of sound for azimuth angles for 1000-ft layers to 10,000 feet. Using prepared graphs, over-pressure intensity and focal points where critical over-pressure will occur are pin-pointed and semi-objectively forecast. This Note should prove beneficial to those units that are faced with providing this difficult forecast of possible damage.

DD FORM 1 NOV 65 1473

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

Security Classification

A PREDICTION METHOD FOR BLAST FOCUSING

INTRODUCTION

During the past several years large non-nuclear bombs (8,000 to 10,000 lb TNT equivalent) have been tested at Eglin AFB, Fla. Under certain atmospheric conditions, the explosions from these munitions have created overpressures which have caused unexpected damages. After several incidents, such as plate glass windows shattering twelve miles away and a communication center nine miles away being knocked off the air, project officials contacted the ADTC Staff Meteorologist for assistance in providing future operational forecasts. Lt John Forsing, a STAFFMET mathematician, attacked this problem initially. Later, a three-man team - - Lt Forsing, Lt Ed Keppel, and Capt Richard Rasmussen - - combined their talents to solve the problem.

After a literature search, the overpressure-forecasting technique established by the Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground, Maryland was selected. This method involves calculating the forecast representative value of the speed of sound for a specific azimuth (based on forecast winds and temperatures) for each 1,000-ft layer from the surface to 10,000 ft. Values of the major positive and negative speed-of-sound gradients are the entering arguments to BRL graphs from which the unfocused overpressure and the focal distance are obtained. A comparison of the speed-of-sound profile with BRL profile categories yields a multiplicative factor for the overpressure intensity. However, the uncertainty involved in selecting focus factors, together with a high rate of unacceptably large predictions of overpressure, suggested the need for further refinement of the BRL techniques for our operational use.

The next source of information came from Kirtland AFB, where STAFFMET personnel furnished us a computerized prediction model, Allsond. This program was originally developed by the Kaman Sciences Corporation, Colorado Springs, Colorado. Unfortunately, Allsond ran into difficulty very soon with its Monte Carlo perturbations, parabolic model requiring rather sophisticated climatology, and its lengthy machine time. It had been designed to be a test model of sound propagation, not an operational model of blast-focusing forecasting. Shortly afterwards, we learned that the NASA Mississippi Test Facility near Slidell, Louisiana had been employing a modified version of the NASA Sound Intensity Prediction Program. This program used only a linear model and did not require as much input data; however, it too had several drawbacks. It required 4 or 5 radiosondes to be released within six hours of actual testing, fixed receivers and mobile communication units blanketing the local area, and exclusive computer privileges during this entire period.

By either of these computerized approaches there would always exist the veiled threat of direct application of the computer overpressure predictions by a customer who did not understand the variable accuracy of inputs and would assume the computer outputs to be

extremely reliable. Both programs used as input the predicted atmospheric values which, of course, could not be expected to verify with 100% accuracy. The computer programs gave the meteorologist no control over the prediction. What was needed was a flexible subjective method which would allow one to temper the forecast, knowing the reliability of the forecast atmospheric parameters. It was decided that the arithmetic advantage of using a computer did not offset the danger of user interpretation of results. Therefore, both programs were eventually discarded.

While the two computer programs were undergoing evaluation, discussions were also held with Mr. Jack W. Reed, Test Effects Department, Sandia Laboratories, Albuquerque. His extensive research and operation in the blast-focusing field proved to be of great value. By placing focus factors and damage limits in probabilistic terms, he had arrived at solutions to the forecast prediction in terms of economics rather than those of absolute safety. Even so, the Sandia method is quite similar to the BRL method, and requires the following information either directly or indirectly: speed-of-sound profiles, ray tracings, a functional relationship of the standard overpressure versus distance, attenuation coefficient, and focus factors. Therefore, in the operational checklist, the BRL and the Sandia methods have been combined, incorporating the most desirable features of both.

Problem Statement

> The problem is twofold. First, using the most recent upper-air data, to forecast the winds and temperatures from the surface to 10,000 ft for mission time. Secondly, to use these forecasted values in obtaining a speed-of-sound profile and determining any significant areas of focusing of the acoustic shock wave and the intensity of the focusing in these areas.

Definitions

Blast Focusing -- The refraction patterns of shock waves through the earth's atmosphere.

Shock waves -- The pressure and sound waves created by an explosion.

Focal Area -- The location upon which the refracted shock waves are expected to be concentrated.

Overpressures -- The pressure expected at various locations due to the refraction pattern of the initial shock wave.

Speed-of-Sound Profile -- A vertical plot of the representative values of the speed of sound.

Reference Angle - The direction (clockwise from north) that one is interested in for determining the amount of focusing expected in that area.

A DESCRIPTION OF THE SPEED OF SOUND AND BLAST FOCUSING

Focusing of an acoustic shock wave is caused by variations of the speed of sound in the atmosphere. These variations are primarily caused by two meteorological parameters, temperature and wind. Moisture and density variations in the atmosphere have such a relatively minor effect that they were not considered in these calculations.

For surface or near surface blast sources, the horizontal changes in the speed of sound contribute very little to the focusing potentials. The horizontal variations of the tempera- and wind fields are not nearly as pronounced as are the vertical shears. Hence, the primary concern is for the vertical changes in the speed of sound since these changes are the main phenomenon responsible for any type of focusing.

In order to determine the vertical changes, an empirical equation is used to calculate the representative speed-of-sound values from the surface to 10,000 ft in 1,000-ft intervals:

$$V_s = 2T - V \cos \gamma \text{ (see note)}$$

V_s = representative speed of sound

T = temperature (C°)

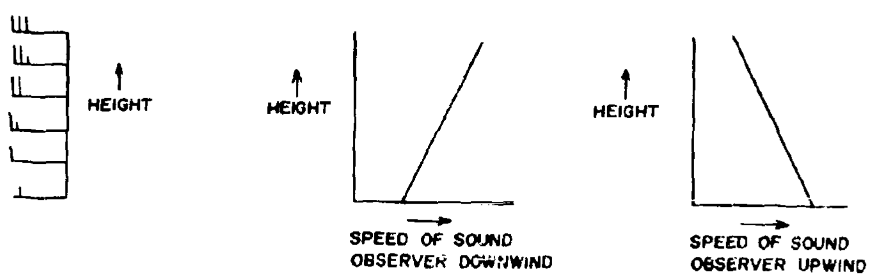
V = wind speed

$\gamma = \theta - \alpha$, where θ = direction the wind is coming from and α = reference angle

Above 10,000 ft, the speed-of-sound changes are neglected. If any shock wave traveled that far upward, it would decay so considerably by the time it was refracted back to the surface that it would be of very little significance.

1. Here are some visual presentations of how the wind and temperature variations each affect the speed-of-sound profile.

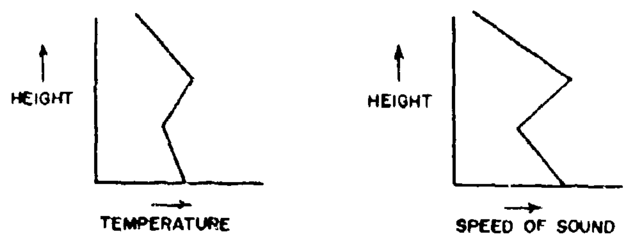
a. Wind Speed Effect (temperature and wind direction are constant with altitude)



NOTE: This equation does not give one an actual value for the speed of sound. It only shows the changes in the speed of sound from layer to layer.

2. In general, the speed-of-sound profile varies directly with the wind variations when one is downwind, and indirectly when one is up wind. This holds true when the wind direction is fairly constant with height, as one can then determine the downwind and upwind location.

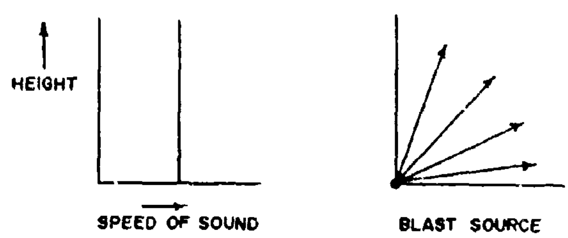
a. Temperature Effect (winds calm at all levels)



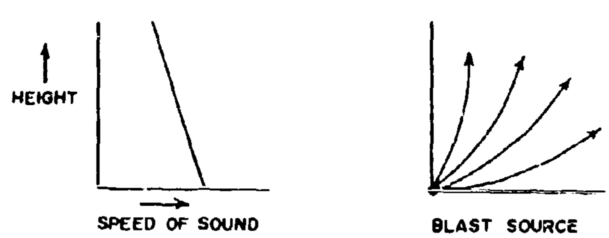
In general, the speed of sound changes about 2ft/sec for each 1°C change in temperature. The stronger the inversion, the more pronounced the focusing.

3. The relationship of the speed-of-sound profile and the focusing of shock waves is based on the following physical principle: When the speed of sound decreases with height, the shock waves are refracted upwards; when the speed of sound increases with height, the shock waves are refracted downward. Many different speed-of-sound profiles are possible. Here are some of the predominant profiles with their associated shock-wave patterns:

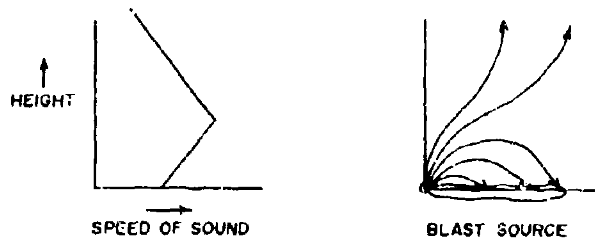
a. Wind is calm and temperature is constant with altitude. (No focusing/standard over-pressure)



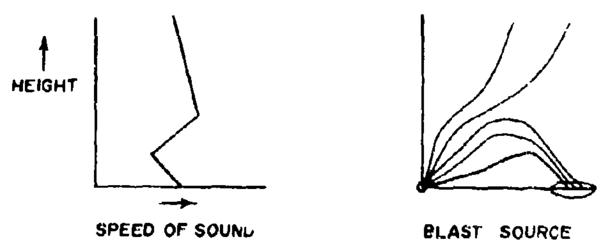
b. Wind and temperature decrease with height, observer is downwind (No focusing/less than standard overpressure)



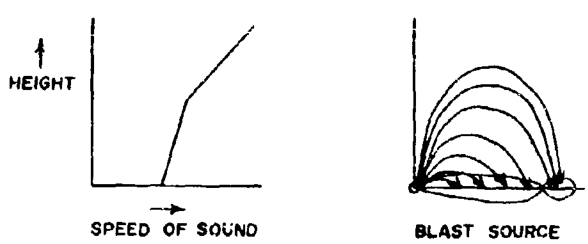
c. Winds and temperature increase then decrease with height, observer is downwind. (No focusing, amplification greater than standard over-pressure).



d. Winds and temperature decrease, increase, and then decrease with height, observer is downwind. (focusing/overpressure and focal distance depending on height and intensity of the speed of sound inversion).



e. Wind and temperature increase slightly, then greater with height, observer is downwind. (focusing and amplification).



In cases 3a through 3e, it has been assumed (for simplicity) that the wind direction is fairly constant with height (within 100 degrees). The speed-of-sound profile can become quite complicated, however, especially when the wind reverses direction and the speed varies. Such conditions will be apparent during the calculation of actual cases.

4. The following generalizations can be quite helpful in calculating blast focusing:

a. The strongest focusing and/or amplification will occur when the wind shears and temperature inversions coincide.

b. The area of strongest focusing will be downwind.

c. Strong winds will generally produce more intense focusing than light winds.

d. The stronger the speed-of-sound inversion, the closer the focal area will be to the blast source and, hence, the more intense the overpressure.

e. The closer the speed-of-sound inversion is to the surface, the closer the focal area will be to the blast source and, hence, the more intense the overpressure.

5. The procedures that are fully described in the checklist Appendix 1 are basically the following: First, forecast the wind and temperature values for each 1000-ft layer. Next, calculate the representative speed-of-sound values for each level, plot them on the worksheet, and determine the major gradients. Apply these gradients to the BRL and Sandia graphs to determine the focusing and/or amplification possibilities. Select the focus factors for both methods, and calculate the intensity of the overpressures. Compare the two answers, and select the one that appears most reasonable.

VERIFICATION

To actually verify such a procedure as this would require considerable sophisticated instrumentation. For the area size with which we are dealing (approximately a 20-mile radius circle for a 10,000 lb TNT equivalent explosion), this has not been possible. The primary verification we can offer are several specific incidents that have happened since this checklist and procedures have been developed.

On two separate occasions, we predicted that overpressures just below the damage criteria would strike Eglin AFB. During both cases, the entire base felt quite an appreciable jolt, yet not one pane of glass was broken. On another occasion we had a critical building, downwind of the drop zone, yet closer than the area of expected focusing. The test was performed, and personnel at the building did not hear anything as the focusing was on the other side of them as predicted. Without our checklist, we certainly would have recommended cancellation on that day. As it turned out, the test was a success.

Since July 70, when our checklist and procedures were put in use, we have had no damage claims, law suits, or even broken windows due to blast focusing. The time used for an initial forecast ranges from a half hour to one hour, depending upon the meteorological situation and specific test area. The time used in providing these specialized forecasts is well justified, due to the significance of this type of non-nuclear experimental testing.

CONCLUSION

By combining the BRL methods and the Sandia reports into a checklist with worksheets, an efficient yet economical operational technique has been devised for forecasting blast focusing.

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Lorrain, P.H., Perkins, B., Townsend, W.H., Forecasting the Focus of Air Blasts Due to Meteorological Conditions in the Lower Atmosphere. Ballistic Research Laboratories Report #1118 (October 1960).

Reed, J.W., Acoustic Wave Effects Project: Airblast Prediction Techniques. Sandia Laboratories Report # SC-M-69-332 (May 1969), pp 7-12, 25-31, 44-58 and 64-86.

APPENDIX 1

BLAST FOCUSING CHECKLIST

PART I

Enter items 1 thru 9 shown below on the worksheets (see Attachment 8).

1. Forecast the wind direction (theta, θ) and speed (V) at 1000-ft intervals from the surface to 10,000 ft for the scheduled time of the mission.

   a. Three key items to consider are the location of the drop zone, the sea-breeze effect, and the amount of heating expected by mission time. Any frontal systems or low-level weather phenomena should also be considered. The lowest several thousand feet are the most critical, so be extremely careful.

2. Using the average wind direction in the first 5,000 ft, determine the 180-degree reciprocal direction (alpha, α), the direction of expected maximum focusing. Also, select the directions (alpha's) of potentially sensitive areas for use in successive calculations. These alphas are the reference angles.

   a. Example: If the winds are from the southeast, then the area northwest of the drop zone would be expected to receive the most focusing. If the winds were from the west, then the area to the east would be the most critical. The first time through the entire calculations one should consider the probable area of maximum focusing. Then, repeating the entire procedure, use any other angle to look at one specific area in determining how that area will be affected.

3. Calculate the relative angle of the wind for each level and represent them as gamma (γ), where $\gamma = \theta - \alpha$.

   a. Example:

θ	α	γ
270°	90°	180°
200°	20°	180°
20°	200°	-180°

4. Using the gamma values and the forecast wind speeds, determine the wind component to the speed-of-sound profile by the graphical computation aid, which gives $V \cos \gamma$.

   a. The graphical wind computation aid is Attachment 9. Be sure to use the wind-velocity scale that is in knots. This computation aid takes the cosine of gamma, multiplies it by V, and converts it to ft/sec. How to use it: Center the ruler on the chart with the wind scale on the angle gamma. Go along the ruler until you get to the forecasted wind speed (in knots). Then read off the value of the $V \cos \gamma$ term on the parallel lines.

5. Determine the sign of the $-V \cos \gamma$ term by looking at the magnitude of gamma. Consider V to be positive.

If γ is from 0° to 90°, then $V \cos \gamma = +$ and $-V \cos \gamma = -$.
If γ is from 90° to 270°, then $V \cos \gamma = -$ and $-V \cos \gamma = +$.
If γ is from 270° to 360°, then $V \cos \gamma = +$ and $-V \cos \gamma = -$.
NOTE: $\cos(-\gamma) = \cos \gamma$

6. Forecast the temperature (T) in degrees centigrade from the surface to 10,000 ft in 1000-ft intervals for the scheduled mission time.

7. Double all the forecast temperature values (2T).

a. For negative temperatures, simply multiply the value by 2 and let it remain a negative number.

8. Add the doubled temperature values (2T) to the wind component ($-V \cos \gamma$) and determine the values for the speed-of-sound profile (V_s), where $V_s = 2T + (-V \cos \gamma)$.

a. This equation is taken from the BRL report. It considers the temperature profile to be twice as important as the wind component. The 2T term is considered to be in ft/sec, i.e., the value 2 has the dimensions of ft/(sec) (degrees).

9. Plot the V_s values versus altitude on the speed-of-sound profile worksheet.

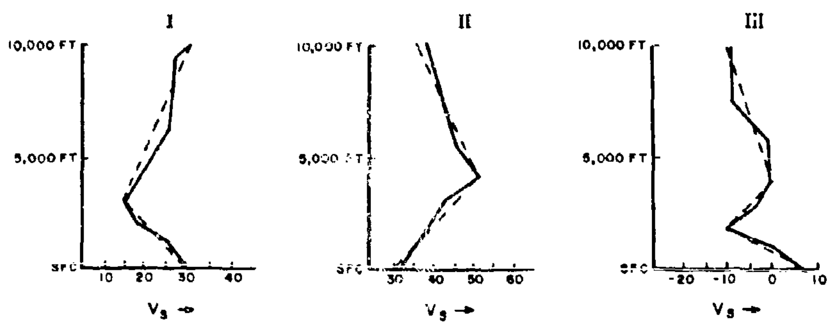
a. The values for the bottom scale (V_s) have been omitted on purpose. Due to the range that the V_s values can have, room did not permit the insertion of various values. It has been left to the discretion of the forecaster, depending upon the values that he determines. Some examples can be seen in the next item.

PART II

INTERPRETATION

10. Determine the first two significant gradients in the speed-of-sound profile. Enter the numerical values of these two gradients and the height of change on the worksheet.

a. Significant gradients are those that are initially negative and become positive at a higher altitude, initially zero then positive, positive then negative, positive then zero, and positive becoming significantly more positive. Smoothing can be applied to insure that the overall pattern is defined, not the trivial fluctuations. In some rare cases one might have 3 or more significant gradients. One must consider all possibilities. If the first significant gradient will not refract a majority of the rays, then the combination of the second and third major gradients could possibly affect the total outcome. (see examples for one of these rare cases).



Examples: Solid Line: Actual Sounding
Dashed Line: Smoothed Sounding

I. Negative (-15/3000ft = -.005), then positive (+15/7000 = +.002).
Height of change = 3000ft.

II. Positive (20/4000ft = +.005), then negative (-15/6000 = -.0025).
Height of change = 4000ft.

III. Negative (-15/2000ft = -.0075), then positive (10/2000 = +.005),
then negative (-10/6000 = .0016).
Height of change = 2000ft.
Neglect the third gradient as it is a weak gradient.

11. If there are no positive gradients, it can be assumed that the overpressure exceeds 4 mb to a range of 16000 ft in all directions for a 10,000-lb ground burst. (Sandia Chart, Attachment 1 to Appendix 1).

a. The value of 16 kft was determined using a zero speed-of-sound profile. (Sandia focus factor = 1.0) Other yields have a value determined by:

$$R = \left[243(\text{Wkt H.E.})^{0.4}\right]^{.833}$$

where

Wkt H.E. = yield in kilotons of high explosive

In fact, this method overestimates the range for negative gradients since focus factors (from Item 14) of 0.2 to 0.9 should be applied. This, however, doesn't produce operationally significant differences. BRL uses a focus factor of 0, which would give us absolutely no safety criteria at all. Due to the large WKT H.E. we are dealing with, we feel that the Sandia results are more representative in the case.

12. If the first major gradient is positive and the second gradient is negative, zero, or less positive, one has no focusing, just amplification. Use the values from Item 10 of the significant gradient and the height of change, and do the following:

a. For the Sandia method, select a focus factor from Item 14. Using Attachment 1 to this Appendix, determine the range where the overpressure is 4 mb for this focus factor.

b. For BRL, take the magnitude of the positive gradient and the height of the gradient top, use Attachment 2 and determine the maximum range of rays returning to the ground. A focus factor is not needed in this case, as it has already been incorporated into the chart.

(1) The focus factor is always used to multiply the overpressure expected, not the distance. For cases of amplification only, one has to use the Sandia chart for different focus factors for determining the distance that one expects 4 mbs overpressure. There is not a linear relationship between distances and focus factors (see Equation for Δp in Item 14b).

c. Comparing this value to the Sandia values, select the lesser of the two. Forecast the overpressure to exceed 4 mb to this distance.

13. If the first gradient is positive and the second gradient is more positive, the prediction method is a combination of Items 12 and 14. Therefore, the predicted areas of overpressures exceeding 4 mb are composed of an expansion of the area close to the blast as well as an area of focusing at a distance.

14. For all other combination of gradients, the following procedure will apply. Take the two gradients and the height of change and determine the focal distance from the charts in Attachment 3.

a. BRL Method: Using Attachment 4, determine the unfocused overpressure expected at the above focal distance. (Convert psi to mb by multiplying psi by 69). Using the BRL profile classification (Attachment 5), determine the focus factor and enter this value on the worksheet. Multiply the unfocused overpressure by this value and arrive at the expected overpressure at that focal distance and direction. Try to be subjective with the higher-valued focus factors (Categories 4 & 5), since a representative value for a "strong" gradient is never given. We would estimate a gradient of .020 or greater could be considered strong.

b. Sandia Method: Take the following three parameters: The focal distance from Item 14, Attachment 1 of Checklist, and the focusing factor expected (from the table below). With these, determine the amount of overpressure expected. Use the following table for the focus factor:

FOCUS FACTOR	SITUATION
0.2	Large negative gradient entire V_s profile
0.9	Slight negative gradient (entire V_s profile)
1.0	Zero gradient (vertical V_s profile)
3.0	Wind shear in lower several thousand feet
5.0	Temperature inversion in lower several thousand feet
6.5	Combination of wind shear and temperature inversion (rare cases!)
8.6	Average of extreme cases of focusing on record
16.5	Highest ever recorded.

The above focus factors that deal with wind shears would apply when calculating for a target directly downwind (area of strongest focusing/amplification). These focus factors become proportionally less as one turns away from the downwind direction. At this time there are no definite relationships among the focus factors, the direction of interest, and the general wind direction. Any such relationship would have to be measured on an instrumented range. For any point in the pressure field of blast regardless of the profile, the following values have been calculated: 99.9% of cases are focus factor "5" or lower;99.9% of cases are focus factor "2" or higher.

(1) Four mb is considered to be the critical limit for glass breakage. Any values less than 4 mb are safe structurally but can still create a lot of noise. Any values above .1035 mb (115 decibals) is considered loud to the average ear. For the predicted overpressure, the following equation applies:

$$\Delta p\,(\text{mb}) = \text{incident overpressure} = kW^{A}R^{-3A}\,\alpha F$$

where , k = constant $\doteq$ 357

W = yield in nuclear kilotons

R = range in kilofeet

A = constant $\doteq$ 0.4

α = viscous attenuation coefficient $\doteq$ 1

F = focus factor (dimensionless)

Also,

P_k = incident peak-to-peak overpressure $\doteq 1.35\,\Delta p = \Delta p + \Delta p-$

$P_k{}^*$ = reflected incident peak to peak overpressure $\doteq 2P_k$

Δp^* = recorded overpressure $\doteq P^*_k \doteq P_k$

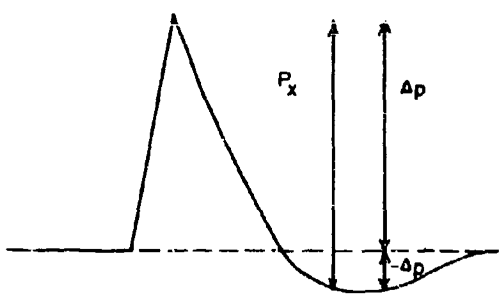
Therefore, 0.4 -1.2

$$\Delta p^* \doteq 482\,W^{0.4}R^{-1.2}F$$

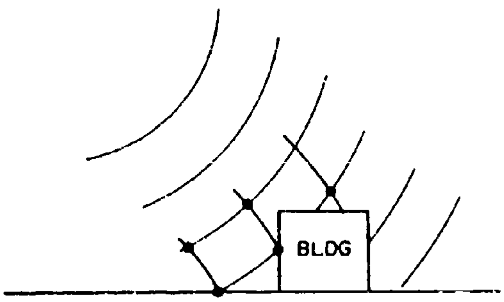
and

$$P^*_k = 2\Delta p^*$$

This is the predicted overpressure (P^*_k)



PRESSURE VS TIME RECORDING



$O = P^{*}_{k}$ = REFLECTED PLUS INCIDENT PEAK-TO-PEAK OVERPRESSURE (The amount of energy lost due to the ground refraction is considered minimal)

15. Compare the BRL results with the Sandia results. One can either combine the results or select the one method that seems to be most applicable for this case. Now refer back to the original forecasted winds and temperature. Attempt to visualize what would happen if one had more heating, less heating, no sea breeze, etc. Then finalize your guesstimate and contact the project officer.

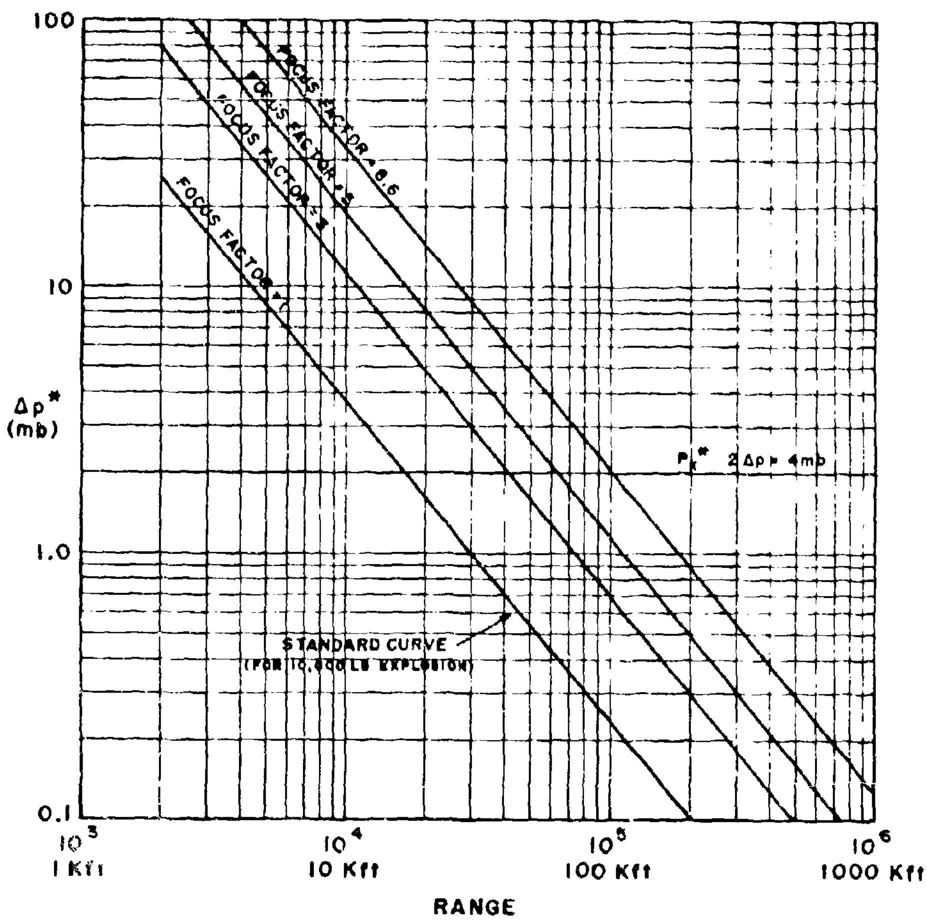
Three examples are furnished:

Example 1 Attachments 7a, b, and c
Example 2 Attachments 8a, b, and c
Example 3 Attachments 9a, b, and c

* Attachment 6 is the design and specifications of a Wind Board.

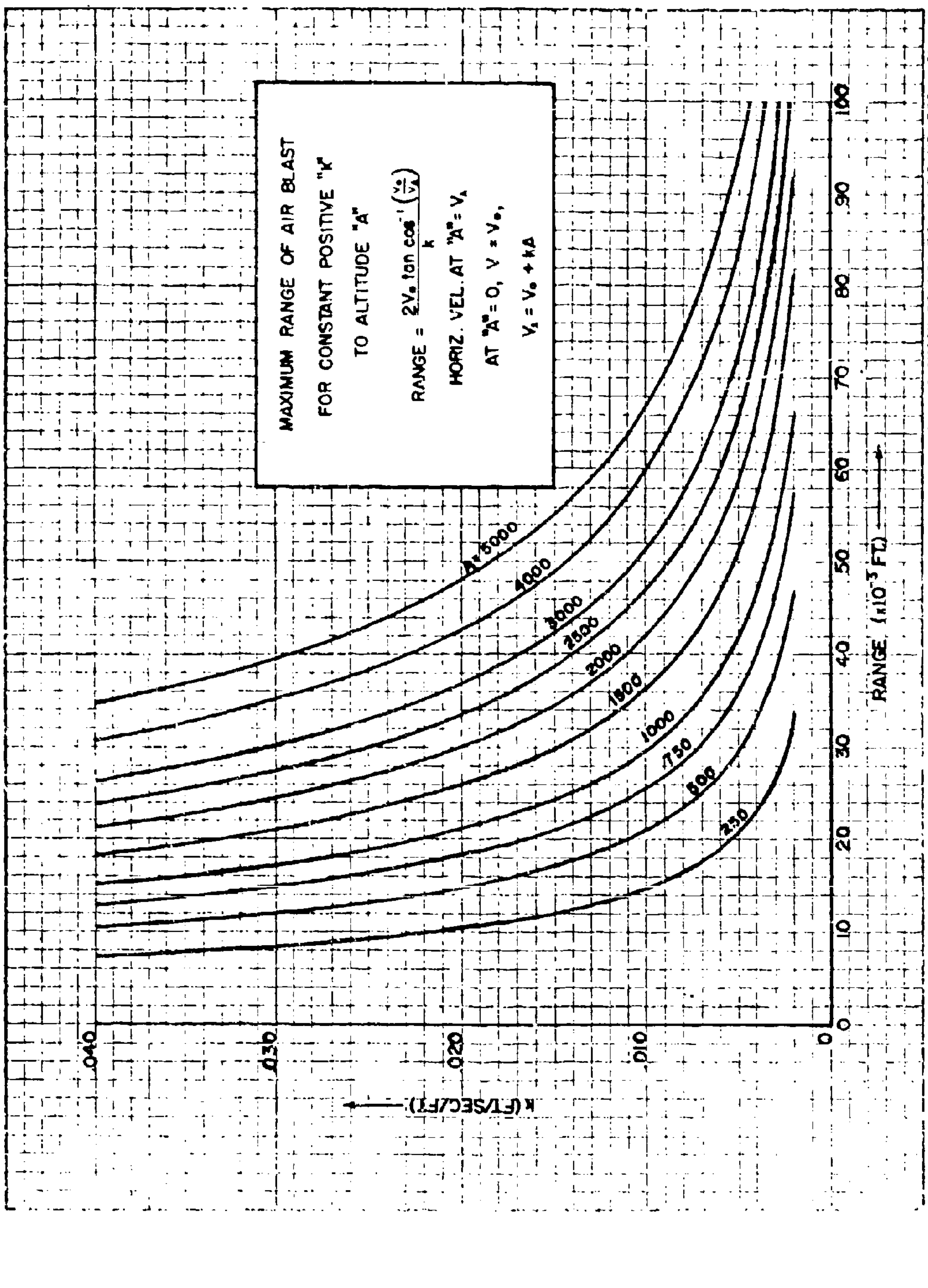
ATCH. 1

SANDIA

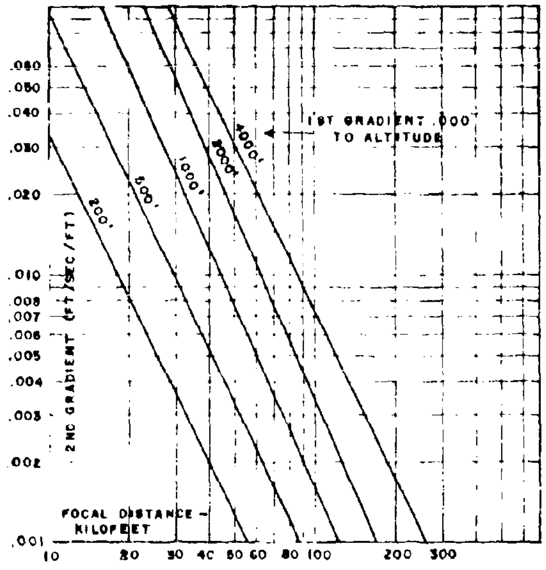


SANDIA Chart for Determining Range for Specific Overpressures and Selected Focus Factors

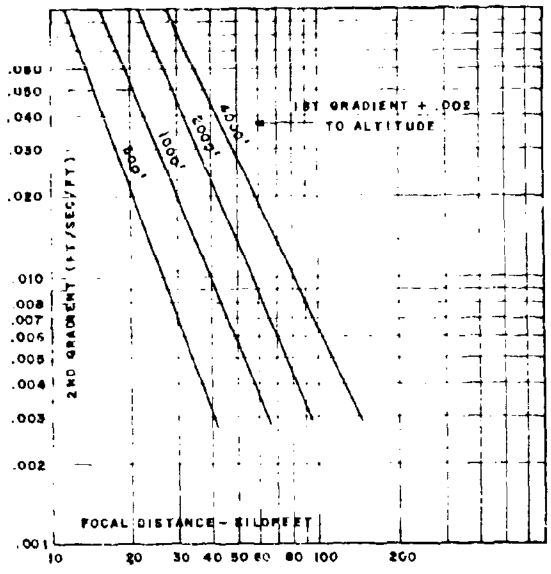
ATCH. 2



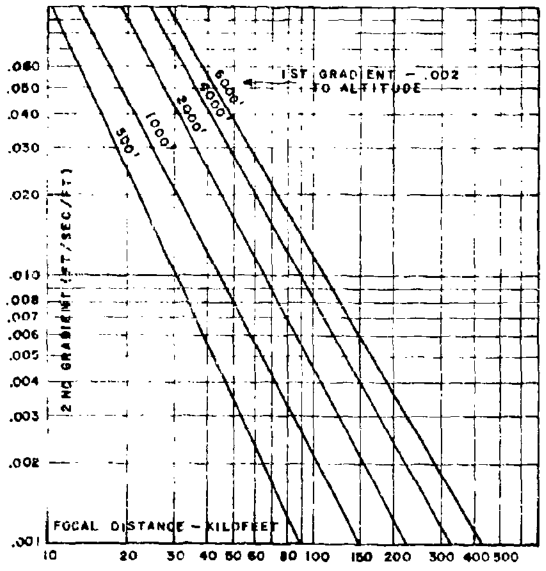
MAXIMUM RANGE OF RAYS WHEN A POSITIVE GRADIENT EXTENDS TO VARIOUS ALTITUDES



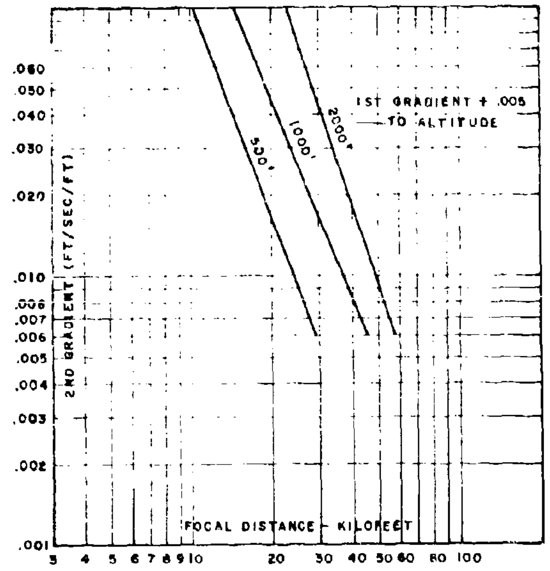
Focal Distance When 1st Velocity Gradient is Zero to Various Altitudes and for Various 2nd Gradients.



Focal Distance When 1st Velocity Gradient is +.002 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

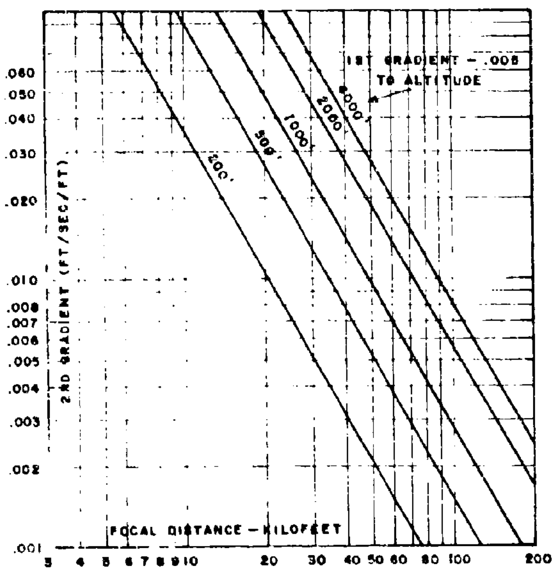


Focal Distance When 1st Velocity Gradient is -.002 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

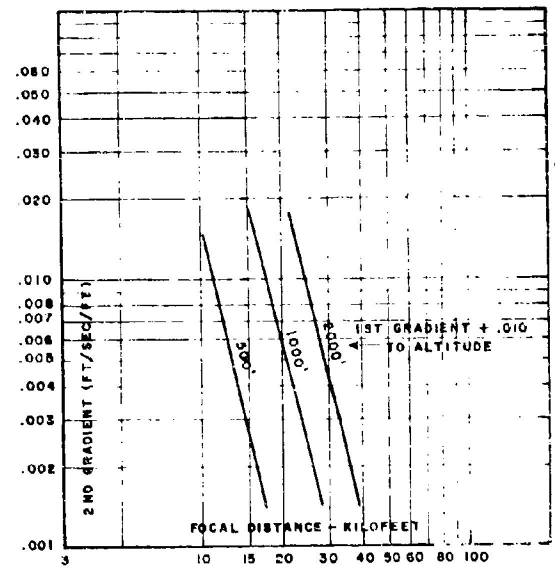


Focal Distance When 1st Velocity Gradient is +.005 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

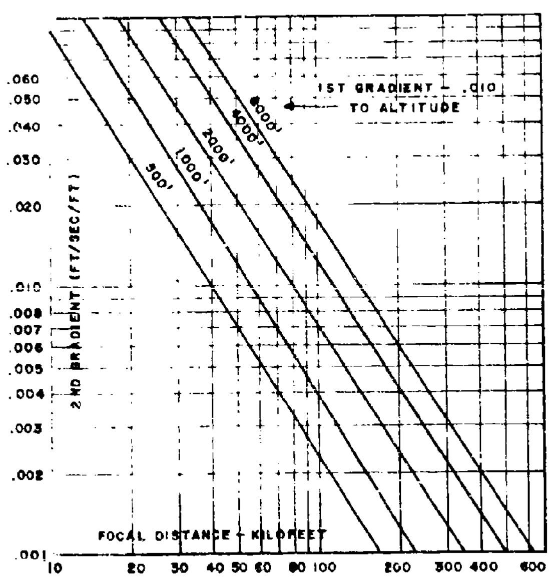
ATCH. 3 (CONT'D)



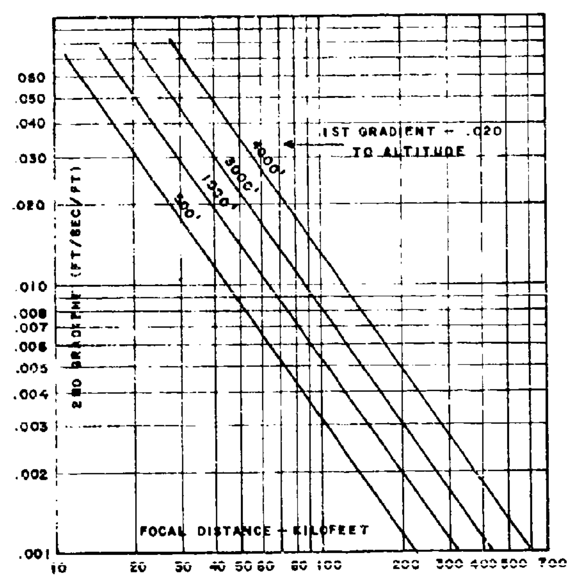
Focal Distance When 1st Velocity Gradient is -.005 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.



Focal Distance When 1st Velocity Gradient is +.010 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

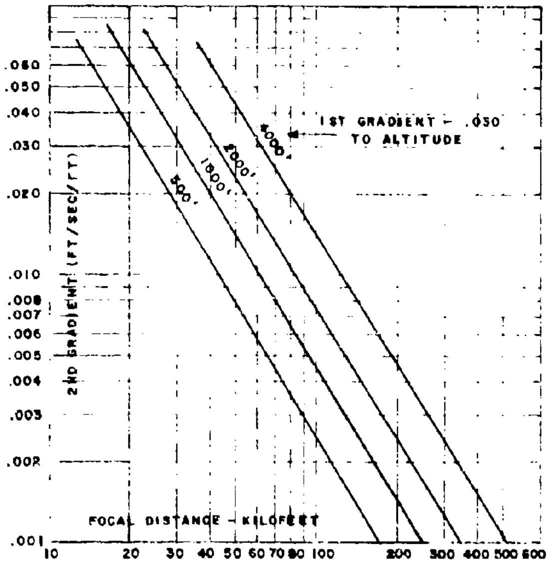


Focal Distance When 1st Velocity Gradient is -.010 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.



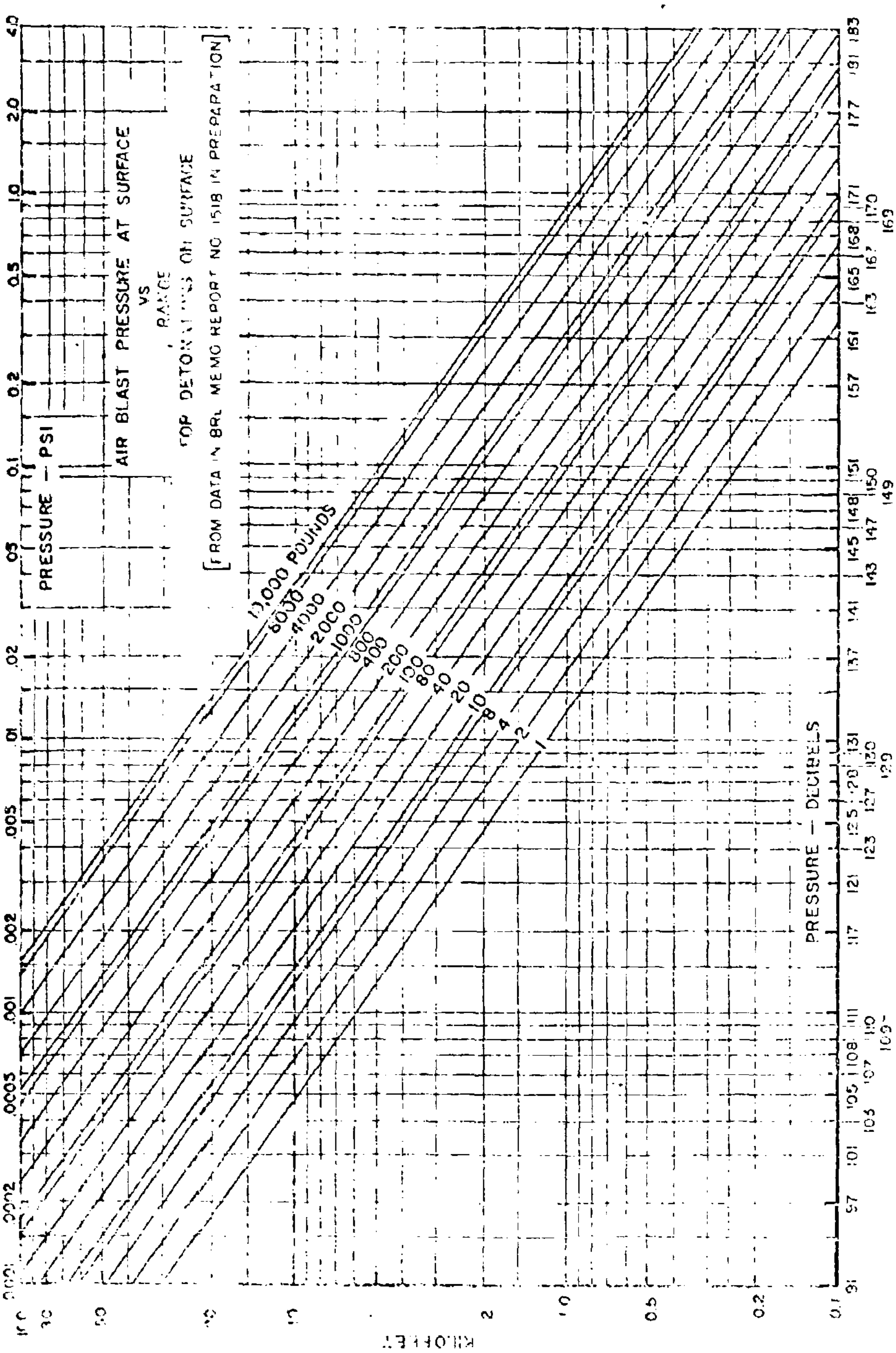
Focal Distance When 1st Velocity Gradient is -.020 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

ATCH. 3 (CONT'D)



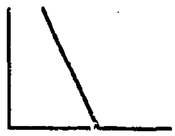
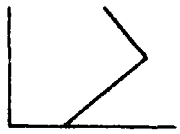
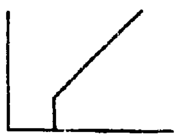
Focal Distance When 1st Velocity Gradient is -.030 Ft/Sec/Ft to Various Altitudes and for Various 2nd Gradients.

ATCH. 4



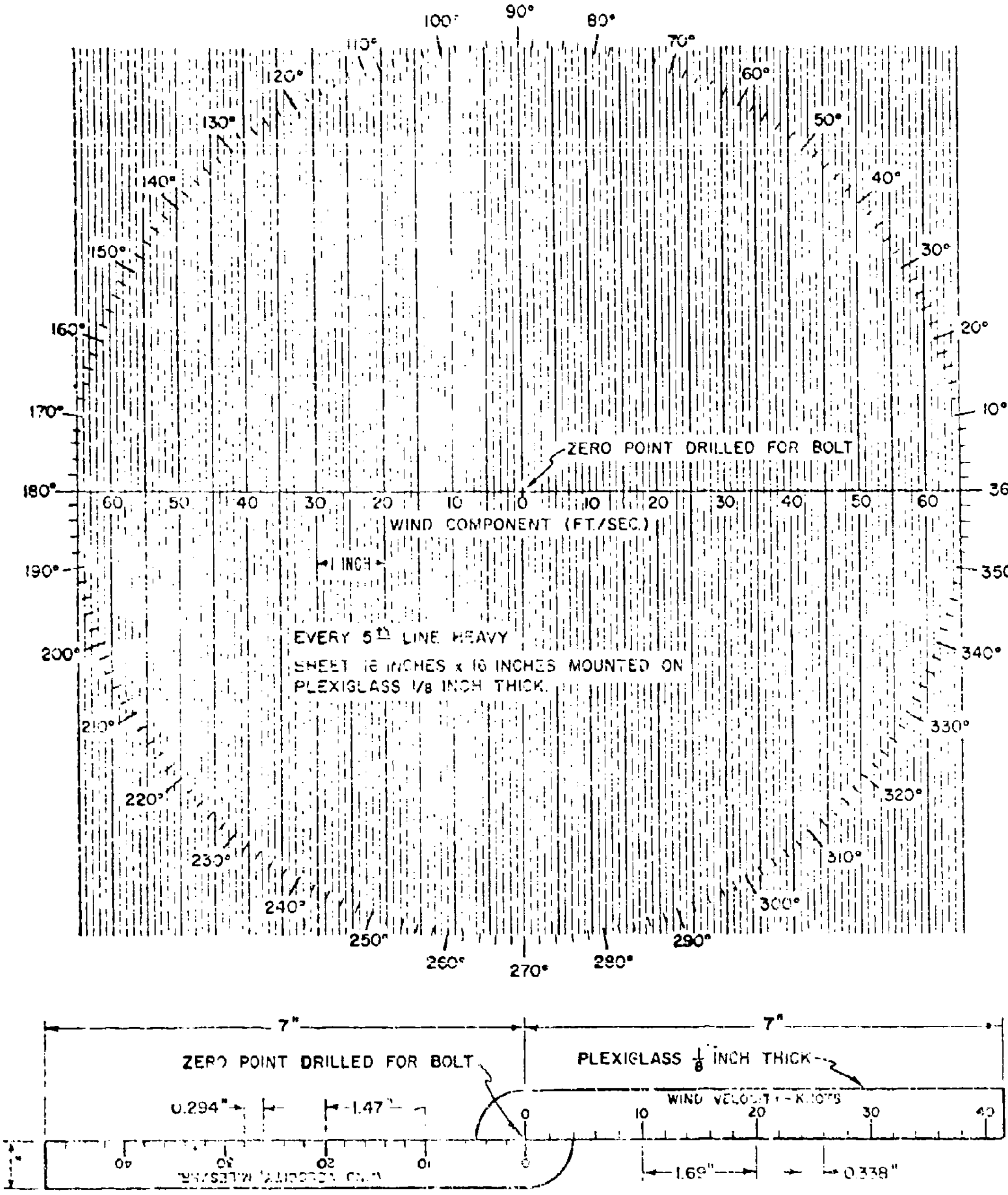
PRESSURE vs DISTANCE WHEN VERTICAL VELOCITY GRADIENT IS ZERO (1963)

ATCH. 5

COMBINATION OF GRADIENTS		MULTIPLICATION FACTOR FOR REGION NOTED
SINGLE NEGATIVE GRADIENT		0 - FROM ORIGIN TO LIMIT OF OBSERVATION
POSITIVE GRADIENT NEAR SURFACE WITH NEGATIVE GRADIENT ABOVE		5 - ORIGIN TO LIMITING RANGE
ZERO GRADIENT NEAR SURFACE WITH POSITIVE GRADIENT ABOVE		10 - FOCAL AREA ONLY
WEAK POSITIVE GRADIENT NEAR SURFACE WITH STRONG POSITIVE GRADIENT ABOVE		25 - FOCAL AREA ONLY
NEGATIVE GRADIENT NEAR SURFACE WITH STRONG POSITIVE GRADIENT ABOVE		100 - FOCAL AREA ONLY

VARIOUS TYPES OF VELOCITY GRADIENTS TO BE EXPECTED AND THE INCREASE IN INTENSITY AT A FOCUS FOR EACH TYPE.

ATCH. 6



ELEMENTS AND DIMENSIONS FOR WIND BOARD

STAFF MET SUPPORT CHECKLIST

STAFF METEOROLOGIST: Capt R.A. Rasmussen

PROJECT #/NAME: 4535K005 Pave Pat II

MISSION #: 5030

RANGE/LAUNCH SITE: Pocosin Pond (12 miles NW of Eglin AFB)

LAUNCH/T.O. TIME/DATE: 0915-1115/13 Nov 70

WX [illegible]: N/A

BRIEFING TIME: 0730/13 Nov 70

PROJECT OFFICER/PLACE OF CONTACT: Capt Carlson

PHONE NUMBER: 2-2517

WEATHER SUPPORT REQUIRED (CHECK P.D., CARD FILE, OPS ORDER, AND PROJECT OFFICER):

Blast Focusing Forecast

NOT REPRODUCIBLE

SYNOPSIS OF SUPPORT RENDERED (REASONS FOR HOLDS, CANCELLATIONS, PROBLEMS ENCOUNTERED AND RECOMENDATIONS):

0730 - Maximum amplification would extend 7.5 miles toward Eglin. This would be cutoff for > 4 mb overpressure. Therefore, looks like a go situation as no critical targets are expected to receive > 4 mb overpressure.

0900 - Surface temps and winds just as forecast - Situation still looks good.

1030 - Mission went. Eglin heard large BOOM, but no damage was reported! We had less than 4 mb overpressure.

ATCH. 7b

BLAST FOCUSING WORKSHEET

TNT EQUIVALENT: 10,000 lbs DATE: 13 Nov

RAOB AVAILABLE: 12Z

DATA MODIFIED?: Yes - Lower level winds & temps

REFERENCE ANGLE: (α) 145° (Eglin AFB)

FORECAST VALUES:

$\lambda = (\theta - \alpha)$

	WINDS	γ	$-V \cos \gamma$	T (t)	2T	Vs
SFC	360/05	215	+7	11	22	29
1 M	360/10	215	+14	10.5	21	35
2 M	310/08	165	+13	10.5	21	34
3 M	280/13	135	+16	8.5	17	33
4 M	270/18	125	+17	9.5	19	36
5 M	270/18	125	+17	9.5	19	36
6 M	275/18	130	+20	10.5	21	41
7 M	280/18	135	+22	10.5	21	43
8 M	280/20	135	+24	10.5	21	45
9 M	275/25	125	+24	9.0	18	42
10 M	270/25	120	+21	7.5	15	36

FIRST GRADIENT: + .002

SECOND GRADIENT: - .005

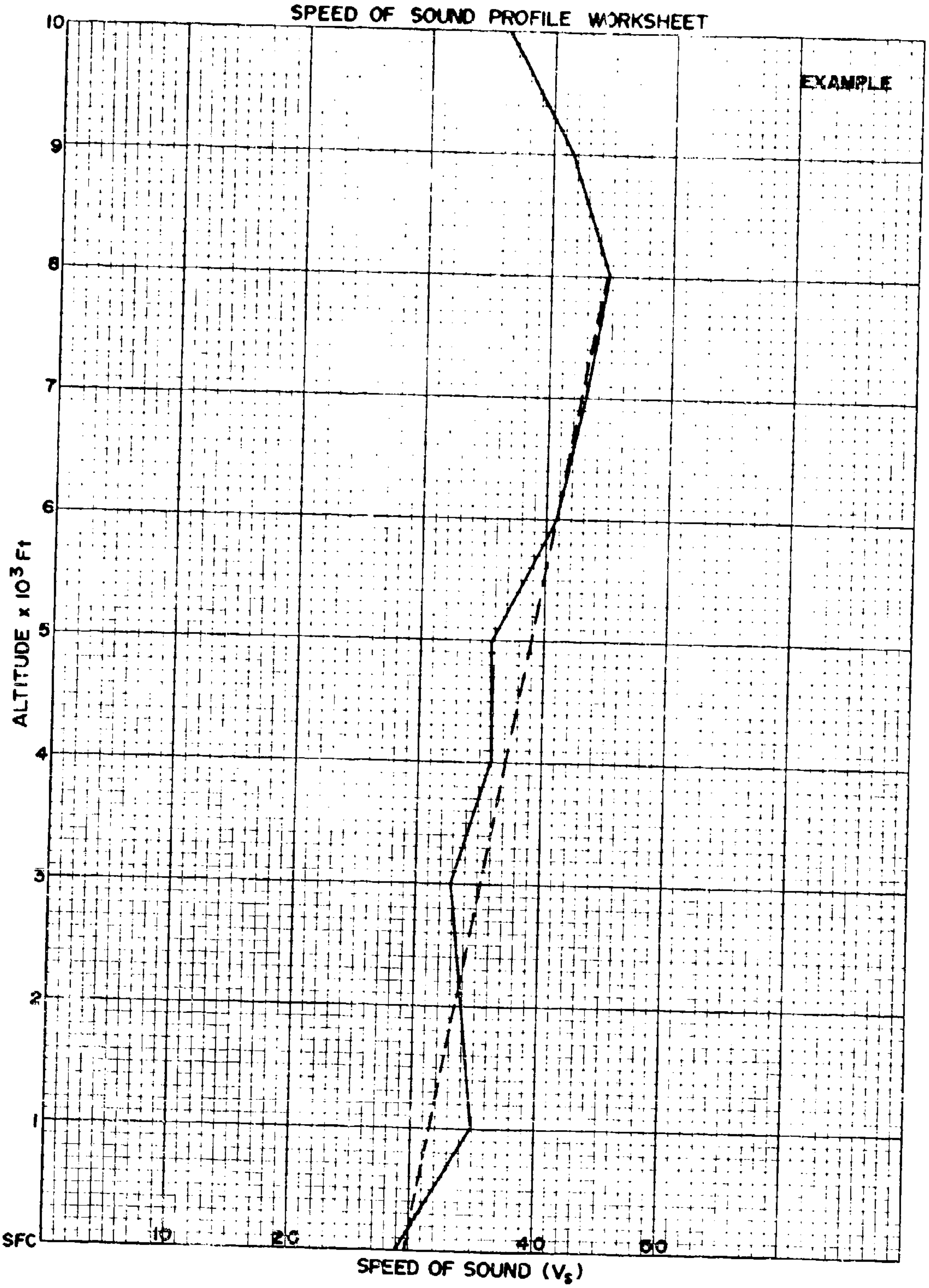
HEIGHT OF CHANGE: 8,000 Ft

FOCAL DISTANCE: N/A Amplification, instead

	SANDIA	BRL
UNFOCUSED OVERPRESSURE:	To 16KF > 4 MB	Off scale as gradients are too weak therefore should stick with SANDIA results!
MULTIPLICATION FACTOR:	X3 (wind shear)	
OVERPRESSURE:	To 40KF >4 MB	MB

1 psi = 68.9476mb

SPEED OF SOUND PROFILE WORKSHEET



STAFF MET SUPPORT CHECKLIST

STAFF METEOROLOGIST: Capt. R. A. Rasmussen

PROJECT #/NAME: 4535K005 PAVE PAT II

MISSION #: 1030

RANGE/LAUNCH SITE: Pocosin Pond (12 miles NW of Eglin AFB)

LAUNCH/T.O. DATE/TIME: 1130 - 1330 16 Nov 1970

WX SCOUT STN/T.O. TIME: N/A

BRIEFING TIME: 0945 16 Nov

PROJECT OFFICER/KEY CONTACT: Capt. Carlson

PHONE NUMBER: 2-2517

WEATHER SUPPORT REQUIRED (CHECK P.D., CARD FILE, OPS ORDER, AND PROJECT OFFICER):

Blast Focusing Forecast

SYNOPSIS OF SUPPORT RENDERED (REASONS FOR HOLDS, CANCELLATIONS, PROBLEMS ENCOUNTERED AND RECOMENDATIONS):

0945 - For the first Gradient I expect only amplification as it extends only to 1000 ft altitude. The BRL distance of 23 Kilofeet looks more reasonable than Sandia's 40 Kilofeet. There are no significant targets within 8 miles, but I am worried about possible focusing effects downwind due to the 4-5000 ft speed of sound increase. This is a rare case where one must consider such possibilities as not all the rays will be refracted in the lower 1000 ft. A lot will be just bent downward. For the leading edge of the base, I expect critical overpressures around 4 mb. As such a good possibility exists for damaging overpressures, I predict a NO-GO situation.

ATCH. 8b

BLAST FOCUSING WORKSHEET

TNT EQUIVALENT: 10,000 lb DATE: 16 Nov 70

RAOB AVAILABLE: 12Z

DATA MODIFIED?: Yes Lower levels

REFERENCE ANGLE: (α) 145°

FORECAST VALUES:

$\lambda = (\theta - \alpha)$

	WINDS	γ	$-V \cos \gamma$	T (℃)	2T	V_S
SFC	360/05	215	6	5	10	16
1M	330/18	185	30	1.5	3	33
2M	330/20	185	34	-2	-4	30
3M	330/20	185	34	-4.5	-9	25
4M	330/18	185	30	-5.5	-11	19
5M	330/17	185	28	1.5	+3	31
6M	330/17	185	28	2.5	5	33
7M	335/17	190	28	2.5	5	33
8M	335/17	190	28	.5	1	29
9M	330/15	185	25	-1.0	-2	23
10M	310/13	165	21	-3.0	-6	15

FIRST GRADIENT: + .017 Focusing -.004

SECOND GRADIENT: - .004 +.014

HEIGHT OF CHANGE: 1,000 Ft 4,000 Ft

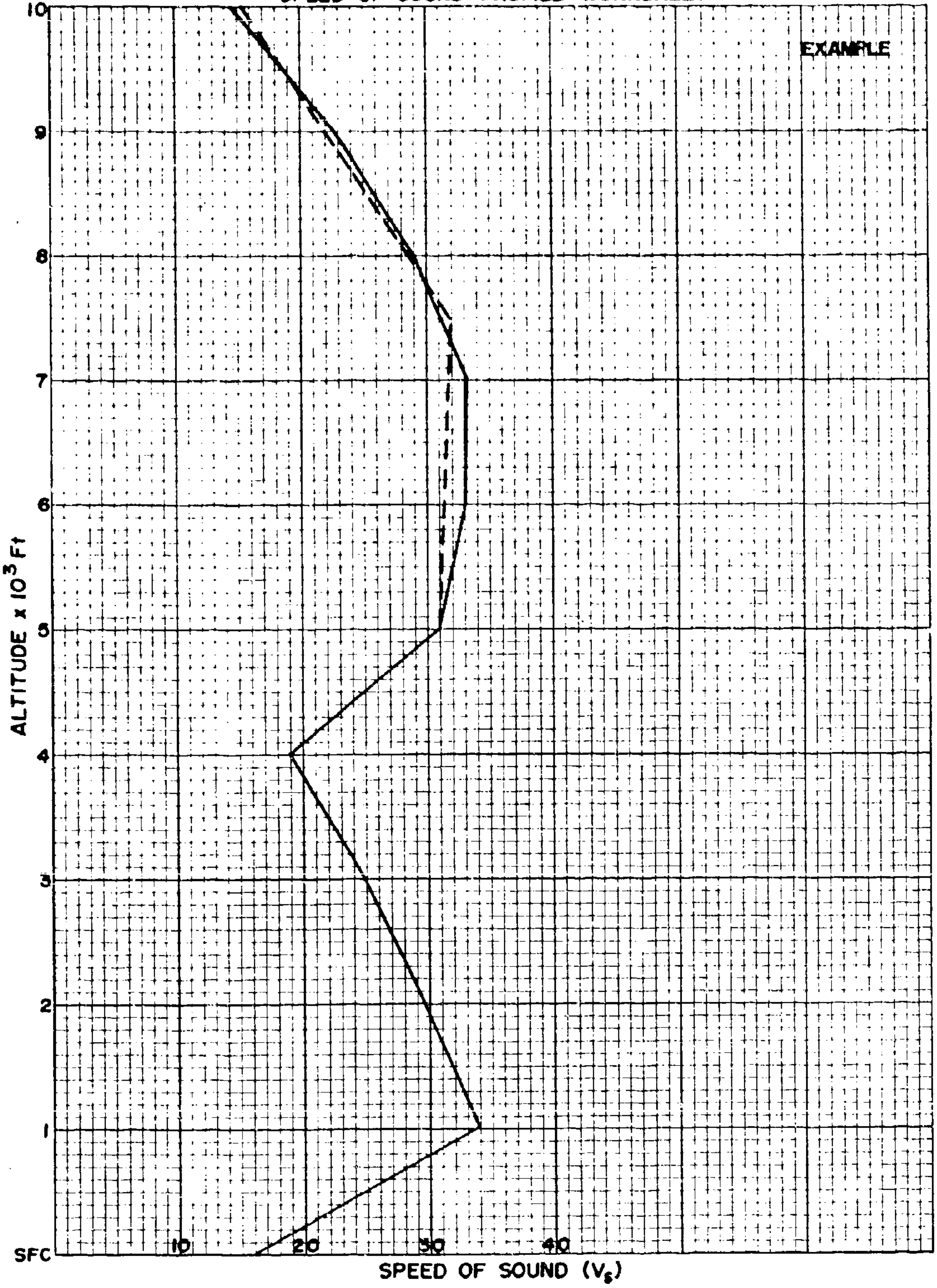
FOCAL DISTANCE: N/A Amplification 65 KF ≈ 13 miles

SANDIA X5
overpressure = 3.8 MB
BRL X20
overpressure = 4.2 MB
1 psi = 68.9476mb

	SANDIA	BRL
UNFOCUSED OVERPRESSURE:	16 KF ≥ 4 MB	–
MULTIPLICATION FACTOR:	X3 (wind shear)	–
OVERPRESSURE:	40 KF ≥ 4 MB	23 KT ≥ 4 MB

ATCH. 8c

SPEED OF SOUND PROFILE WORKSHEET



STAFF MET SUPPORT CHECKLIST

STAFF METEOROLOGIST: Capt R.A. Rasmussen

PROJECT #/NAME: 4535K005 Pave Pat II

MISSION #: 3034

RANGE/LAUNCH SITE: C-52. Populated area 14 miles SW. Site C-6 8 miles east.

LAUNCH/T.O. DATE/TIME: 1215-1400 25 Nov 70

WX SCOUT SCHED/T.O. TIME: N/A

BRIEFING TIME: 1045 L

PROJECT OFFICER/TEST CONDUCTOR: Capt Carlson

PHONE NUMBER: 2-2517

WEATHER SUPPORT REQUIRED (CHECK P.O., CARD FILE, OP ORDER, AND PROJECT OFFICER):

Blast Focusing Forecast

SYNOPSIS OF SUPPORT RENDERED (REASONS FOR HOLDS, CANCELLATIONS, PROBLEMS ENCOUNTERED AND RECOMENDATIONS):

1045 - For 090° - focusing should be on the other side of site C-6 onto an unpopulated area. The intensity of the focusing is doubtful - Sandia focus factor - only used X5 as wind shear was not too strong - speeds were light! BRL focus factor - way out of line as gradients aren't that strong (est. <.02). either way - focusing will occur on other side of critical target. For 240° - no sweat - such light focusing and gradients are almost all negative or zero - no problem at all.

1300 - Mission successful. People at C-6 didn't hear a thing.

ATCH. 9b

BLAST FOCUSING WORKSHEET

TNT EQUIVALENT: 10,000 lb DATE: 25 Nov 70

RAOB AVAILABLE: Yes 12Z

DATA MODIFIED?: Yes Lower level winds & temps

REFERENCE ANGLE: (α) ~~90° (for site C-6) and 240~~ (towns)

FORECAST VALUES:

$\lambda = (\theta - \alpha)$

	WINDS	γ	$-V \cos \gamma$	T (c)	2T	V_s
SFC	140/08	50 -100	-9 3	10	20	11 23
1M	120/10	30 -120	-15 9	3	6	-9 15
2M	100/05	10 -140	-9 7	-1	-2	-11 5
3M	360/04	270 120	0 3	1.5	3	3 6
4M	330/05	240 90	+4 0	2.5	5	9 5
5M	330/12	240 90	+10 0	4.0	8	18 8
6M	335/16	245 95	+11 3	3.5	7	18 10
7M	330/18	240 90	+15 0	3.5	7	22 7
8M	330/18	240 90	+15 0	3.5	7	22 7
9M	325/20	235 85	+20 -3	2.0	4	24 1
10M	320/20	230 80	+21 -6	2.0	4	25 -2

FIRST GRADIENT: -.011 -.009

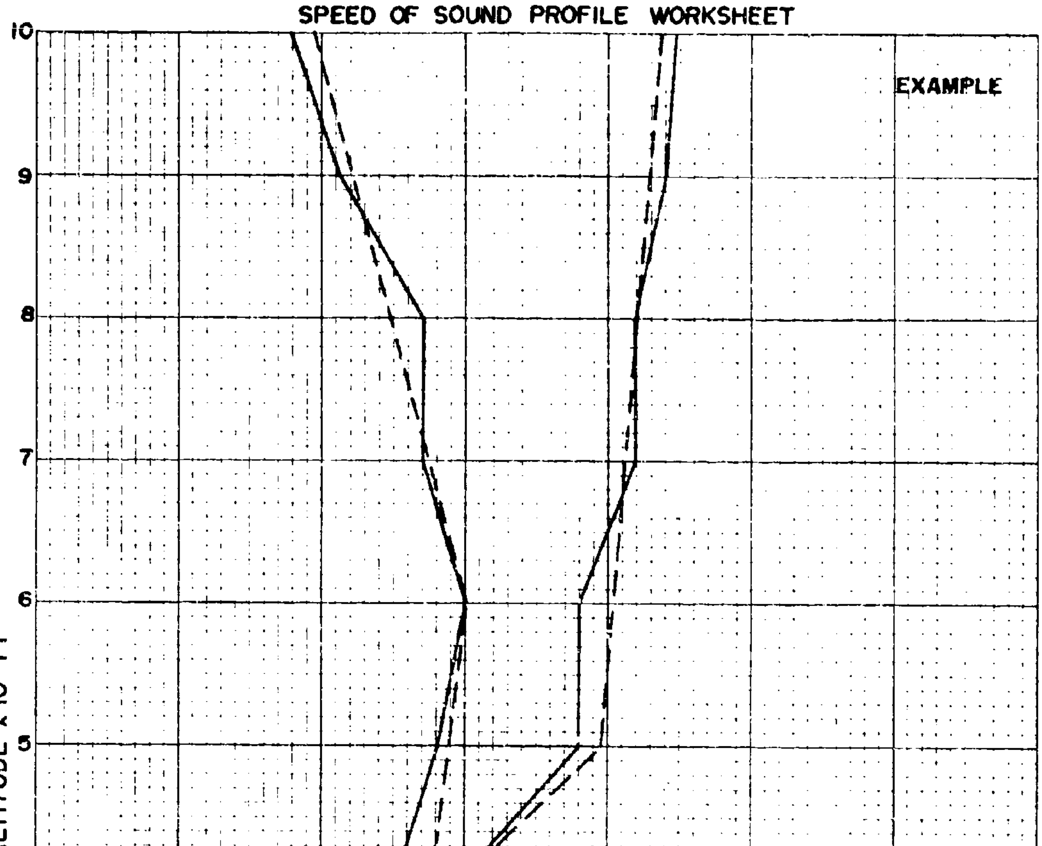
SECOND GRADIENT: +.011 +.001

HEIGHT OF CHANGE: 2000 Ft 2000 Ft

FOCAL DISTANCE: ≈ 72 KF ≈ 13.6 miles 340 KF ≈ 65 miles

	SANDIA	BRL	
UNFOCUSED OVERPRESSURE:	.7 MB	.0025 PSI ≈ .175 MB	1 psi = 68.9476mb
MULTIPLICATION FACTOR:	X5 temp & wind shear	X100	
OVERPRESSURE:	3.5 MB	17.5 MB	

SPEED OF SOUND PROFILE WORKSHEET



AD-732765

CHANGE
January 1972

A PREDICTION METHOD FOR BLAST FOCUSING

1. USAFETAC Technical Note 71-8, September 1971, is presently undergoing revision and will be reissued at a later date. Pending receipt of the revision, the following pen and ink corrections should be made in the existing copies:

Page	Action to be Taken:
3, line 7	last word should be "temperature"
A-1, line 29	change "Attachment 9," to "Attachment 6"
A-4	in bottom line, "2" should be ".2"
A-5, line 15	insert "$\frac{1}{2}$" in front of P_k^*
A-5, line 16	omit "0.4 - 1.2" after the word "Therefore"
A-5	in drawing, "P_x" should be "P_k" and "$-\Delta p$" should be "$\Delta p-$"
A-7	Equation on right side of graph should be "$P_k^* = 2\Delta p = 4$ mb"

2. After necessary action, file this change in front of page 1.

RICHARD A. RASMUSSEN
Captain, USAF
Detachment 10, 6WWg